

desire or caprice of the photographer. This meant that the negative image had to be under observation during the development process, and for this reason dish or tray development was preferred to all other methods. The opposite process was development by time, in which all negatives were developed for a definite time without special control.

It was argued on behalf of individual development that errors of exposure could be corrected and the gradation of the negative controlled to suit the positive material.

In order to see just how far these claims are true, we must examine the possibilities of influencing the negative characteristics in and during development. Is there, in fact, any true foundation for such claims?

We already know (page 35) that time of development has an influence on gradation and density. The longer the development, the steeper the gradation (higher gamma value), until a definite limit is reached (gamma infinity). If we set out the growth of blackening of the negative for different development times in the form of a diagram showing the various steps of blackening as on page 27, we shall reveal the actual character of the development process. We shall see graphically that with increasing time the steps are steeper, but that finally they form a kind of platform (= maximum blackening of the negative), and the density no longer increases.

The possibility of controlling gradation in this manner was of importance in the early days of photography because the photographer had only one type of paper at his disposal, and that paper had only one gradation. In those far-off days, when only albumen paper could be obtained, the photographer aimed at obtaining a negative which would produce a good print on that paper; that meant that he had to produce a negative that was neither too hard nor too soft. Hence when his subject was contrasty he developed for softness by giving a comparatively short development, but when his subject lacked contrast he had to give a long development and to obtain a medium contrast negative. His desire for a developer of a versatile character and for a method which gave reasonable control of the negative is therefore understandable. He preferred to work with a developer which changed its properties on dilution, on variation of the relative quantities of its constituents, and which produced different results according to the time of development applied.

The position of the modern photographer is quite different. He has at his disposal a range of papers of almost infinite variety of contrasts and can therefore produce a good print from any negative whether it be hard or soft in gradation. Moreover, he cannot give individual treatment to a single exposure because his film provides a series of exposures which it is, in general, quite impracticable to handle separately. So, development by time is rarely possible.

The various formulae in this book, when used for the times indicated in each case, produce negatives having the characteristic of a "normal" negative as defined on page 65. Where the negatives are of contrasty objects a soft gradation paper is used, and a hard gradation paper for soft negatives. Hence what the earlier photographer sought to obtain, often unsuccessfully, by manipulating the development process is today more easily and certainly obtained by choosing the right grade of printing or enlarging paper.

#### COMPENSATING DEVELOPMENT

In a somewhat similar manner photographic technology today deals with another question, namely the rectification of errors in exposure. How it does this can be made clear by reference to our density staircase or steps on page 25.

What effect has an error in exposure on the building up of the silver image of our negative? If we give too short an exposure only the lower part of the staircase will be developed; with a longer exposure the scale will be extended towards the upper part.

The great exposure latitude of modern negative material permits so long a tone scale that there is actually room for quite considerable errors of exposure. The actual differences between negatives which have received different exposures is not in gradation, as can be seen on page 37, for the steepness of the steps is the same over the whole range, but in the fact that the densities of the longer exposed negative lie higher up the scale than is the case with short exposures. In printing this means that negatives of short or long exposure can be printed on the same paper, but those with the heavier or higher densities or blackening require a longer exposure in printing as compared to those which have had a short or normal exposure.

We can now ask what effect development time has on the various exposed negatives? If we compare the range of densities of a negative which has had a short development time, with another which has received normal development, we shall see that short development has given us a lower contrast and densities. That means that we must use a contrasty paper for printing and a short exposure. So far as the finished prints are concerned there will be no serious difference between them, and the same will apply in respect of errors of exposure, whatever variations we may adopt in the development process.

In fact, the great exposure latitude of modern sensitive material is sufficient in itself to bridge over errors in exposure in the great majority of cases. There are some special exceptions which we shall discuss in the section dealing with developer formulae (page 172), but as a general rule it will be well to avoid any tricks or special techniques in the actual development.

#### DISH OR TRAY DEVELOPMENT

In early days this was the most widely-used method of development. Today it finds application in the handling of single plates or films. We have already seen that it affords the possibility of observing the growth of the image during development and, to some extent, influencing the process. Let us gather together the various factors that can influence the character of the negative and arrange them as a short set of rules.

- (1) A strongly diluted developer results in a soft negative.
- (2) Increased development time increases contrast.
- (3) The stronger the concentration of the developer the more quickly it will develop, and the more speedily will high contrast be reached.
- (4) With home-compounded developers increasing the alkali content provides a means of accelerating the rate of development and therefore contrast. This procedure requires great care, otherwise there is the danger that fog will be produced.

The way in which the properties of a developer can be varied by altering its composition is shown in Table XVII.

The table shows how it is possible to obtain nine variants of this particular developer, so that almost every type of result from a very soft to a hard gradation can be obtained.

A dash in the table denotes no change in the standard formula under the particular heading of the column.

It will be seen that in No. 1 the hydroquinone content is 60 grains (3 grams) and the soda is 2 ounces (50 grams) and a very soft working developer is obtained. No. 2 is somewhat more contrasty as only the hydroquinone is altered; in No. 3 the hydroquinone is increased to 100 grains (5 grams) and the soda content is as in No. 1.

In No. 4, the higher hydroquinone content results in more brilliant, that is somewhat harder, results. In the variations 5-9 the chemical composition of the developer is not altered but the degree of dilution is varied and so an increasing degree of brilliance or hardness is attained.

XVII.—VARYING OF FOCAL UNIVERSAL M.Q. DEVELOPER 16

| Effect | Quantity of Hydroquinone | Quantity of Alkali   | Degree of Dilution | Minutes of Developing |
|--------|--------------------------|----------------------|--------------------|-----------------------|
| Soft   | 1 60 grains or 3 grams   | 2 ounces or 50 grams | 1 : 7              | 5                     |
|        | 2 80 grains or 4 grams   | —                    | 1 : 7              | 5                     |
|        | 3 100 grains or 5 grams  | 2 ounces or 50 grams | 1 : 5              | 5                     |
| Normal | 4 100 grains or 5 grams  | —                    | 1 : 5              | 5                     |
|        | 5 —                      | —                    | 1 : 10             | 5-6                   |
|        | 6 —                      | —                    | 1 : 7              | 6-7                   |
| Hard   | 7 —                      | —                    | 1 : 5              | 7                     |
|        | 8 —                      | —                    | 1 : 1-2            | 4-5                   |
|        | 9 —                      | —                    | Undiluted          | 3-4                   |

The temperature of the developer is very important, and it should be kept at 68°F. (20°C.) as it greatly affects the development process.

A low temperature slows down development and hinders the building up of density, while a high temperature accelerates the process and introduces the additional danger of fogging.

Dishes or trays for developing are made of plastic, glass,

porcelain or stainless steel and should be rigorously reserved for their special purpose. They should never be used for other photographic purposes such as fixing, for which separate vessels should be provided. If the dishes in use are of the same size and material they should be marked with a waterproof paint, D for developing, F for fixing, so that there shall be no confusion and no mixing of dishes. Metal dishes or tanks other than of stainless steel must be coated with a good chemical (preferably rubber based) paint for protection.

Plates or films for development are laid into the dish sensitive face upward, and care must be taken to ensure that the developer flows evenly and quickly over the whole of the surface. This is best achieved by tilting the dish slightly so that the solution accumulates at the lower end, then placing the plate or film in the dish, quickly lowering the raised end so that a wave of developer flows quickly but smoothly over the whole of the plate or film surface. A little wetting agent added to the developer will avoid the risk of air bubbles sticking to the surface of the emulsion and retarding or even preventing development in those areas.

The dish should be kept in gentle movement, by rocking, during the whole time of development to ensure even action of the developer. This is particularly important in view of the retarding effect of potassium bromide (see page 91), which can accumulate locally in the developing film and cause uneven development if the developer does not flow freely over the developing surface.

One can now observe the beginning and the progress of the development process, and if the necessity arises, make such corrections as seem called for. In the normal handling of negatives we may meet with the three following possibilities: (1) Correct exposure. (2) Under-exposure. (3) Over-exposure.

(1) *Correct Exposure.* As we shall see later (see page 231), the appearance of the first trace of the image and the way in which the image builds up varies somewhat with different developers, but the normal order of appearance and development is as follows.

The first to appear are the highlights, those parts of the subject photographed which were most brilliantly lit; next come the well-lit parts, then the half tones and finally the details of the shadows, that is, the darkest or least lit portion of the picture.

The density and gradation of the negative can be roughly judged by looking at the back of the plate or film and choosing the right moment for stopping the development process, that is, the moment that it has reached the desired character. If the negative appears too soft or thin, development is continued until every important detail in the picture is visible. If greater contrast is required, then the time of development will be increased until it is obtained.

(2) *Under-Exposure.* This is shown during development by the appearance of the highlights, then much more slowly the other details and the half tones appear, but the details in the shadows refuse to appear even after excessively long development.

A badly under-exposed negative cannot be saved by any manipulation of the developer. Those parts of it which received no exposure or an insufficient amount cannot be developed, for there is nothing there to develop. It is therefore quite wrong in such a case to attempt the use of a concentrated developer, the effect of which will be to exaggerate the contrast of that part of the image which has developed without in any way improving the rendering of shadow detail.

The old-fashioned remedy of diluting the developer is equally fruitless, for there is nothing in the negative to be saved. At the best all that we can do is to make use of some method of after-treatment (see page 339), or choose a more suitable grade of printing paper.

(3) *Over-Exposure.* This shows itself in development by the whole image flashing up quickly, and not merely the highlights: that is always an indication of over-exposure.

It is not an indication to stop development; on the contrary, the process should be continued until the negative is fully developed right through. True, the image will be dense and the whole negative dark but, thanks to the latitude of modern materials, the gradation will be a usable one. If the development be stopped too soon the negative will be too flat.

#### JUDGING THE NEGATIVE

It must be accepted that a certain amount of experience is necessary in order to judge correctly the character of a

(10 ml. in 500 ml.) of the working bath. Exposures should be doubled.

The addition of the developer improvers will give bright negatives of good printing quality, and is recommended where maximum emulsion speed is not essential. They are also useful for known over-exposure.

There have been numerous other formulae put forward as fine-grain developers, about some of which the most extravagant claims have been made. In quite a number of cases upwards of a dozen constituents are included, and it is not infrequently found that some of them are incompatible with the other constituents, or merely perform the same function. Such formulae, better called recipes, are like some old remedies into which all kinds of weird ingredients were added in the hope that even if they did no good they could do no harm.

#### HIGH-DEFINITION (HIGH ACUTANCE) DEVELOPERS

This group has become one of the most important because the developers it includes lead to negatives of enhanced acutance and prints of good image sharpness (see page 58).

To make full use of the advantages of this type of developer it is, of course, advisable, as we have already seen on page 62, to choose a fine-grain, thin-emulsion film of low or medium speed. It is doubtful whether, for these films, fine grain developers are the best to use. Modern films of this type are already so fine in grain that there is really no need for further improvement. Nevertheless, it is important to get the best possible result as far as negative quality and emulsion speed is concerned.

To get the optimum negative quality with these thin emulsion films the problem must therefore be approached in a quite different way. Let us consider the various properties a developer should have to give the best results with fine grain films. These films tend to yield excessive contrast and one of the properties of the developer should therefore be the reduction of contrast. However, while the contrast should be reduced the gradation must not suffer i.e. the tone scale must not get too restricted. We, therefore, need basically a soft-working developing agent such as metol. It should also be a compensating developer (see page 139) i.e. the concentration

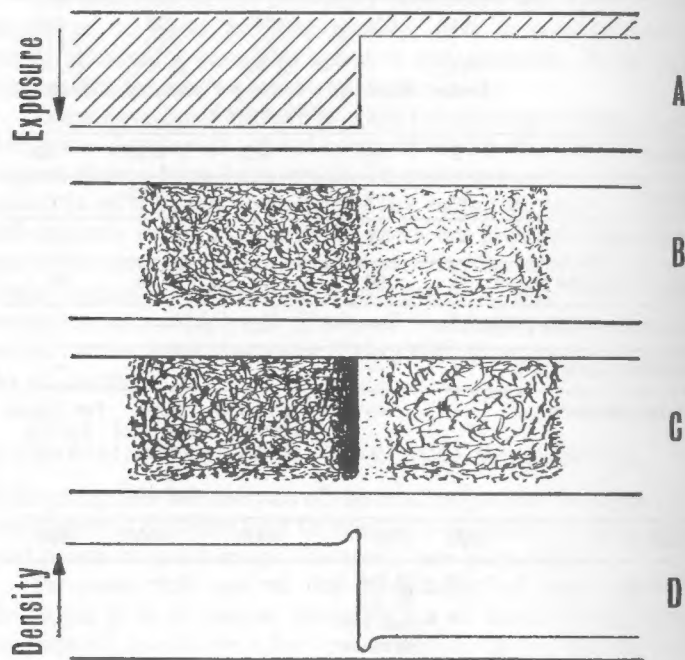
#### XXXIV.—SPECIAL DEVELOPERS High Definition

|                         | 105<br>W.<br>Beutler | 106<br>Windisch   | 107<br>FXI<br>G. W.<br>Crawley<br>(Brit. Journ.) | 108<br>FX2<br>G. W.<br>Crawley                    | 109<br>FX13<br>G. W.<br>Crawley |
|-------------------------|----------------------|---|--|---|---------------------------------|
| Metol                   | 5                    | —   | 0.5  | 0.25  | 0.5                             |
| Glycin                  | —                    | —   | —  | 0.75  | —                               |
| Pyrocatechin            | —                    | 12.5  | —  | —   | —                               |
| Sodium sulphite anhyd.  | 25                   | 80  | 5  | 3.5   | 40                              |
| Sodium carbonate anhyd. | 25                   | —   | 2.5  | —   | 2.5                             |
| Potassium carbonate     | —                    | —   | —  | 7.5   | —                               |
| Special additions       | —                    | —   | Pot. Iodide<br>0.001%<br>5 ml.                   | Ilford<br>Desensitol<br>Yellow<br>Sol.<br>3.5 ml. | Pot. Iodide<br>0.001%<br>5 ml.  |
| Water to                | 1000                 | 1000  | 1000   | 1000  | 1000                            |
| Dilution                | 1 : 10               | 25 ml. +<br>15 ml.<br>Pot. Hydroxide<br>10% +<br>960 ml.<br>water | —  | —   | —                               |
| Development Time (min.) | 7-10                 | 15-20   | 15   | 15  | 10                              |

of the developer should be comparatively low so that it exhausts rapidly in the highlight areas. But a diluted developer may not develop shadow details adequately, which amounts to a loss of emulsion speed, so the alkali content should be relatively high.

Such a developer, having a low concentration of developing agent, the activity of which is maintained by high alkali content, has at the same time a tendency to produce the border effects which we have mentioned before (page 77). The diluted compensating developer becomes quickly exhausted over the dark areas where a lot of silver halide has to be developed. The exhausted developer meets active





The active developer of light areas carries over and continues to develop the edge of the dark area while the exhausted developer of the dark area migrates to the light area and retards development there. The result is that the "sharpness" is increased due to the higher edge contrast. High definition developers are based on this effect.

developer at the border of the dark area and the action of both naturally spreads somewhat in the neighbouring areas. The result is that the active developer of the light area carries over and continues to develop the edge of the dark area. On the other side the exhausted developer of the dark area migrates to the light area and retards development there. The result is that the "sharpness" of the outline is increased due to the higher edge-contrast (page 216).

Table XXXIV gives formulae for a number of such high-definition developers. They are all characterised by the fact that the concentration of developing agent is very low, approximately in the region of only .5 grams per 1 litre. However, the activity of the developers is maintained by a comparatively high alkali content. In Formula 106 the compensating effect has been increased by the choice of pyrocatechin as a developing agent which has a selective imagewise tanning effect on the gelatine of the emulsion (page 222).

These developers are also characterised by the absence of bromide which enhances local developer exhaustion at the boundary between high and low density areas. Agitation of these developers must be carefully controlled because too vigorous agitation neutralises the adjacency effect and too little causes streamers.

All these high-definition developers can only be used once. It is, therefore, advisable to make them up either in the form of a concentrated stock solution or in the form of two solutions, of which one contains the developing agent and sulphite in 500 ml. of water, and the other the sodium carbonate in the remaining 500 ml.

## INVERSION AGITATION

It has already been mentioned (page 78) how important it is to agitate the film in the tank properly, especially when spiral tanks are used for development. In these tanks the coils of the film are quite close together and unless the solution is kept on the move, the negatives may not be evenly developed. Rotating the spiral with a stirring rod is not a fool-proof method as agitation may not be quite even.

Inversion agitation eliminates the danger of uneven development. Many modern tanks are provided with a plastic cap which fits over the pouring opening of the tank lid. With

J. H. Altman<sup>12</sup> found that "Except for a certain thiocyanate developer, all the developers studied gave substantially the same resolving power for practical gammas or image contrasts."

Resolving power is an attribute of definition in a photographic image, but because it is influenced by so many factors, simple measurements are unable to provide a fundamental relationship that is consistently meaningful. Neither the resolving-power values derived from high-contrast objects nor those from low-contrast objects are a unique measure of definition.<sup>13</sup> Not only resolving power but also graininess, sharpness, and tone reproduction are involved in an observer's impression of the clarity of detail of a photographic image. Sharpness is thought to be the major determinant, however. Unfortunately, sharpness is another subjective concept, the impression received by an observer when viewing an image containing the boundaries of clearly resolved elements of detail.

### IMAGE SHARPNESS

The sharpness of photographic materials, according to R. E. Stapleton,<sup>14</sup> is affected by two factors—the grain size of the developed image and the image diffusion or image spreading caused by the scatter of the exposing light. Image diffusion may be modified by development effects occurring between adjacent developing areas. The structure of the developed silver image depends upon graininess resulting from the dispersion of the metallic silver particles from development.

Individual silver particles would not be a factor in image graininess even at great magnification, as the individual particles are much too small to be resolved. In image areas of uniform, intermediate density the distribution of the silver particles may produce the mottled appearance—graininess—that becomes objectionable to the eye. According to Philip A. Friedell,<sup>15</sup> spherical areas caused by air bubbles, devoid of silver halide, in the emulsion layer also contribute to the grainy appearance of the image. At a suitable magnification, this nonhomogeneous nature of the particulate image caused image definition to deteriorate, resulting in a loss of image sharpness. However, air bubbles in a coating, or even holes where the silver halide grains have been fixed out, are usually thought to have a small effect as compared to that of light scatter.

The image of a sharp edge is affected by the scatter of the exposing light, ranging from a few microns in the finest-grained layers of low turbidity up to nearly 0.1 mm for a heavy exposure in a high-scattering emulsion layer (according to Stapleton). The results of the more gross effects may be detected by the eye at lower magnifications than are needed to perceive the graininess

of the image. Light scatter depends on the color of the exposing light as well as the size, number, and separation of the silver halide crystals of the photographic material.

Sharpness is the impression a human being gets when observing the detail in a photographic image. This impression is the result of studying the transition of the density of the image at the boundary of a light and a dark area. When photographic materials are given knife-edge exposures—that is, one area of the photographic material protected from the light, the adjacent area unprotected—the image density does not drop to zero in the protected area, but the density gradually decreases from the edge boundary into the area shielded during exposure. This encroachment of the light by reflection, refraction, diffraction, and scattering represents a loss of light from the edge of the exposed area. The diffuseness of the edge boundary is less with fine-grained photographic materials of low turbidity than with coarse-grained materials of high turbidity. (See Figure 2.)

In 1953 G. C. Higgins and L. A. Jones<sup>8</sup> proposed to measure instrumentally the diffuseness of the edge boundary of a knife-edge exposure and use this as an objective measure of sharpness. A microdensitometer, an instrument capable of recording the density, or degree of blackness, of very minute areas, was used to scan across the boundary of the knife-edge image. It was hoped that a maximum change in density from the exposed to the unexposed area, or the maximum gradient recorded by the microdensitometer profile of the density variation at the boundary, could be a measure of the image sharpness of various film materials. This, however, was found to be untrue.<sup>16</sup>

When viewing the edge of a photographic image, the human eye scans back and forth across the edge at about 50 to 100 times per second. The cones of the eye respond to the suddenness of the change in the illumination from the edge being scanned. Jones and Higgins<sup>17</sup> derived a mathematical definition of sharpness called acutance that involved both the gradient of the change in density across the knife-edge image and the total density difference between the dense and clear parts of the negative.

Acutance, the objective correlate of sharpness, was compared with the results obtained by 20 observers ranking the sharpness of 10 different negative materials. All materials were ranked and spaced the same on the acutance scale as they were on the subjective sharpness rating scale. Acutance, however, did not correlate well with resolving-power measurements, just as sharpness did not correlate with resolving power. Higgins and Wolfe<sup>1</sup> reported that "When graininess and tone reproduction are constant and resolving power is adequate to reproduce all the detail that can be observed under the conditions of viewing, acutance correlates well with definition. On the other hand, when the resolving power is not adequate to reproduce all the detail that can be observed, it is also an important determinant of definition."

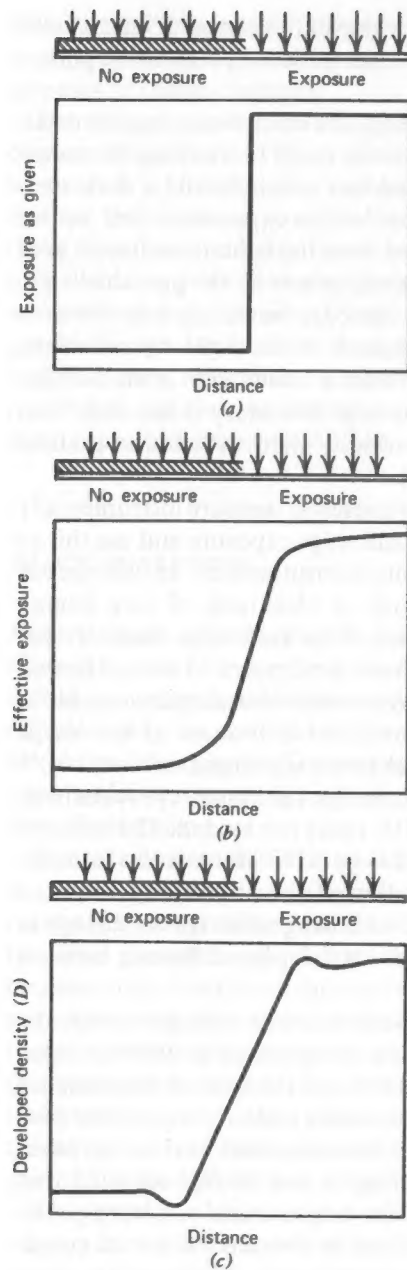


Figure 2. (a) Exposure as given represents sharply defined areas of exposure and no exposure in the emulsion layer. (b) Scattering of the exposing light across the boundary between exposure and no exposure makes the differences in exposure between these areas. (c) The developed density may exhibit edge effects that increase the density in the dense areas and decrease the density in the less dense areas.

Although more complex methods are now used to appraise the total performance of the various elements in a photographic system as described by Perrin<sup>7</sup> or Higgins,<sup>18</sup> the concept of edge sharpness has been valuable in the formulation of developers. The responses of various film products may be rated for a given developer, time of development, and color of the exposing light.<sup>19</sup> Even the more recent measurements of the modulation transfer characteristics of the emulsion, the effect on the microstructure of the image as a result of diffusion of light within the emulsion layer, are subject to modification to some extent by development edge effects.<sup>17</sup>

## DEVELOPER EDGE EFFECTS

Photographic definition is influenced by uneven development effects that occur at the boundaries of image detail. These development edge effects, often called adjacency effects, can cause irregular changes in the size, shape, or density of the photographic image, especially observable at the boundary between areas of high and low development.<sup>20</sup> Adjacency effects are caused by local chemical changes in the developer occurring during the development period, and they may either enhance or restrain the amount of the silver image that would normally be formed.

Certain development effects have long been associated with unsuitable agitation of the solution during development.<sup>21-25</sup> When photographic film is oriented vertically during development, or the film is pulled through the solution as in a continuous processing machine, white streaks may appear near areas that contain considerably more image than adjacent areas. Black streaks may form below an area of low image development. Lack of agitation will cause uneven image development. According to E. R. Bullock,<sup>26</sup> "In ordinary development with vertical immersion and without agitation a downward current prevails, and the degree of development is accordingly somewhat greater near the top than near the bottom of the negatives; under usual conditions the density difference due to this cause is of the order of 5 percent or 10 percent." (See Figure 3.)

Light streaks on the negative, usually extending downward from a vertically developed image, or following after a developed area that has been machine processed,<sup>27-31</sup> are called bromide streaks. These streaks are the result of the restraint of development produced by the release of bromide ions, iodide ions, dyes, or organic restrainers from those areas of the emulsion where a high degree of development is occurring. These inhibitors of development, being added to the developer and increasing its weight over the surrounding solution, tend to trail from areas of high development, producing less image formation than the surrounding developer of normal composition. Such restraint of image formation is minimized by adequate agitation to



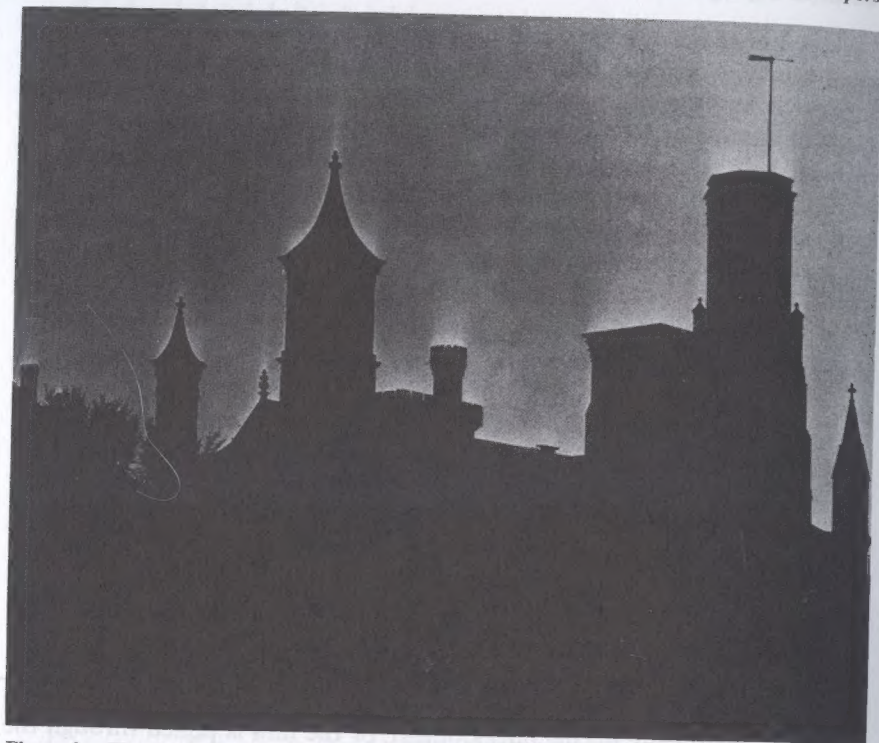


Figure 3. The sheet film negative of the Smithsonian Institution was developed vertically in a tank. The sky area was at the bottom of the vertical film. Unused developer from the silhouetted towers (very little exposure) moved into the nearby exposed sky area, causing increased development. This increased negative development resulted in the light streamers visible on the print from this negative. (Photograph by Grant Haist)

sweep away these unwanted products of development. The most efficient agitation involves swabbing the surface with a brush, sweeping the surface with a reciprocating paddle, or using a jet of liquid or bursts of rising gas bubbles.<sup>32-35</sup>

A developer effect may also produce dark streaks on the negative. Active, unused developing solution from an area of low or no development may diffuse to an adjacent area of high exposure, resulting in an increased reduction of silver there. Generally, under conditions of low agitation, the developer in an area of high exposure will be exhausted rapidly, releasing development-restraining by-products, so that the diffusing fresh developer will cause an increase in the rate of development over that which normally would have occurred. Agitation may be provided in a number of ways, as shown by Figure 4.<sup>35</sup>

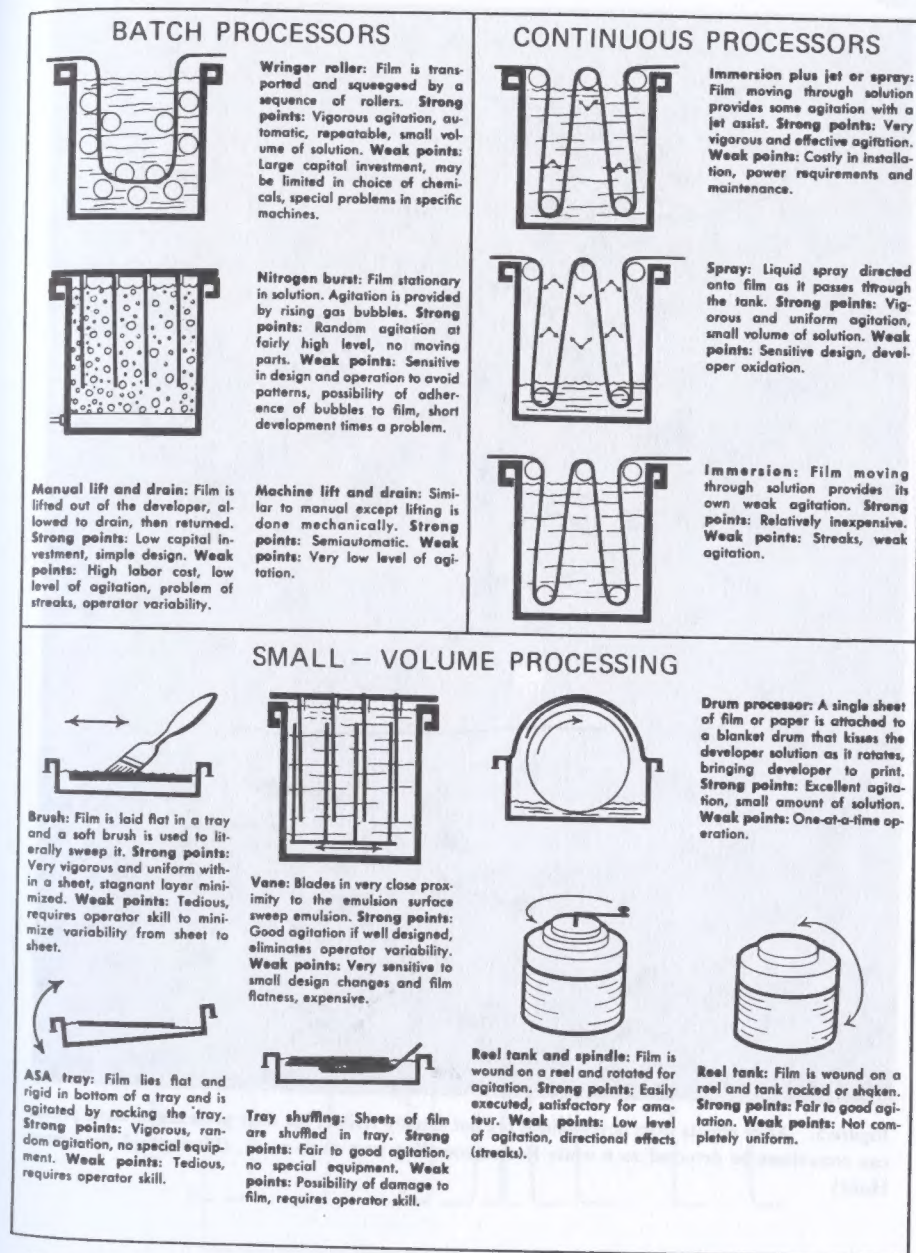


Figure 4. Some methods of agitation during development. [Richard D. Zakia and Hollis N. Todd, *PMI (Photo Methods for Industry)*, 8 (6): 33 (1965)] Reprinted from *Photomethods Magazine*. Copyright © 1965 Ziff-Davis Publishing Company.



from the adjacent clear area will diffuse into the exposed area, producing the greatest increase of density at the very edge. The development increase produces less density as the distance increases into the dense area. The name "Mackie line" is often given to the white line that may surround dark objects in photographic images.<sup>36-41</sup>

Another development effect, the Eberhard effect, named after Gustav Eberhard,<sup>42-47</sup> is a special case of the border effect. Eberhard found that in many cases the density of the developed image was related to its size. Small images were found to have higher densities than large ones, even though both areas had the same exposure and development. In images of small area the image enhancement of the border effect extends across the entire image width. In fine detail on a negative the border effect causes the final density to be higher for small detail than it would be without the effect, thus improving the negative's acutance. (See Figure 6.)

## HIGH-DEFINITION DEVELOPERS

The border and fringe effects increase the density difference at the boundary between image detail of different exposure. Fine line detail is enhanced by the Eberhard effect. In very recent years efforts have been made to compound developers that use these edge effects beneficially to give increased edge contrast to yield improved image definition. Such developer compositions are used with thin-layer, fine-grained photographic films of low or moderate speed. The thin emulsion layer limits the amount of light scatter for a point that occurs as a cone of light focused with the point at the surface of the photographic emulsion. Fine-grained emulsions provide the low graininess suitable for images of high definition and do this without the need for a developer that promotes fine-grain development by the use of solvents or underdevelopment.

Fine-grain developers may achieve the desired result, but the detail of the image may have diffuse or fuzzy edges. Harold Harvey<sup>48</sup> has noted that with *p*-phenylenediamine developers "Despite their fineness of grain, the images had extremely poor resolving power. Micro examination of many films revealed the fact that image areas were softened, those of dark areas against light not holding a sharp boundary. I at first ascribed this to irradiation, but subsequent work led me to believe that it is a characteristic of all *p*-phenylenediamine developers." Willi Beutler<sup>49</sup> found that any developer containing a high concentration of a silver halide solvent will give unsharp negatives with a loss of fine shadow detail near the emulsion surface. Even the quantity of sodium sulfite should not be greater than necessary to act as a developer preservative.

The importance of increased edge contrast has been recognized as a primary requirement for high-resolution development. Geoffrey Crawley<sup>50</sup> has pointed out that

If print definition is to be good, then the contrast of fine detail in the negative must be good. Negatives are printed in an enlarger, and as is well known, light-scatter is produced in the negative as the beam of light from the enlarging lamp passes through it, producing a kind of flare. Flare reduces contrast, and thus the more flare there is, the less contrast of fine detail will tend to be when projected on to the printing paper.

Hence, a negative which has a weak silver grain structure may be inclined to give softer print detail than one with a stronger structure. What produces a weak grain structure?—a fine-grain developer for one thing. Hence, we have two types of developer commonly used: the maximum or high-definition type, which is designed to produce a 'stronger' grain structure, even if it results in a slightly less fine-grained print in order that brilliantly crisp print outlines and detail can be obtained; the second type of developer in common use is the fine-grain developer, with its solvent action on the silver bromide crystals in the emulsion which assists the silver grains formed by the action of the developer to avoid clumping into coarse-grain structures giving a grainy print. This type definitely gives a finer grain, which can be essential with fast films or on some medium-speed ones when very big enlargements are to be made. The flare effect in the grain structure will also give a softer-looking print overall—not so vigorous that is, quite apart from questions of definition and sharpness. Between the two developer types there will sometimes be no great difference in resolution, but the better contrast of detail given by the maximum definition type will probably make the viewer think that resolution is better.

The use of fine-grain developers yields fine grain with a loss in sharpness of the image; the developer designed to utilize edge effects to increase image definition does so at the expense of increasing the graininess of the image. The possibility of providing developers that improve both the graininess and sharpness was the objective of a study by J. H. Altman and R. W. Henn.<sup>51</sup> They compounded two sets of developers: (1) fine-grain developers based on Kodak Developer D-25 with constant Elon concentration but with increasing amounts of sulfite ion and (2) high-definition developers containing low sulfite and a low Metol concentration such as was suggested by Beutler. The exact composition of these two series of developers is shown in Table 1.

In the fine-grain series of developers, as the sulfite concentration was increased, speed and granularity decreased as the rate of solution of the silver halide was known to increase. When the rate of silver halide solution reached a maximum and then began to decrease, the speed and granularity increased in a fashion to suggest a more-than-accidental relationship. With a constant sulfite concentration and thus constant solvent action, reducing the Metol concentration resulted in an increase in acutance without a serious loss of speed except for a high-speed film such as Kodak Tri-X film. Granularity, however, increased for a fine-grain film such as Kodak Panatomic-X.

Table 1. Constituents of Developers

| Series              | Formula No. | Kodak Elon (g/liter) | Sodium Sulfite (anhydr.) (g/liter) | Sodium Bisulfite (g/liter) | Total Sulfite (M/liter) | Kodalk (g/liter) |
|---------------------|-------------|----------------------|------------------------------------|----------------------------|-------------------------|------------------|
| I (Fine-grain)      | AH-1        | 7.50                 | 10                                 | 0                          | 0.08                    | 4                |
|                     | AH-2        | 7.50                 | 30                                 | 5                          | 0.29                    | 0                |
|                     | AH-3        | 7.50                 | 100                                | 15                         | 0.95                    | 0                |
|                     | AH-4        | 7.50                 | 200                                | 20                         | 1.80                    | 0                |
| II (High sharpness) | AH-15       | 2.50                 | 10                                 | 0                          | 0.08                    | 4                |
|                     | AH-16       | 1.00                 | 10                                 | 0                          | 0.08                    | 6                |
|                     | AH-17       | 0.50                 | 10                                 | 0                          | 0.08                    | 20               |
|                     | AH-18       | 0.25                 | 10                                 | 0                          | 0.08                    | 20               |

Acutance continued to increase to the lowest concentration of the Metol which was tried. These results, as given by Altman and Henn,<sup>51</sup> are summarized by Tables 2 and 3.

Fine-grain development and high-sharpness development are not possible with the same solution. Results vary from one emulsion type to another, making generalizations impossible, some emulsions giving a more beneficial balance of results than others. A compromise must be made to secure the best speed-graininess-acutance relationship. Altman and Henn observed that "variations in Elon and sulfite concentrations have resulted in very much greater changes in granularity than in acutance." This is why the fine-grain developers (Series I) appear in general to be advantageous on a basis considering both graininess and acutance.

A high price must be paid in granularity by the high-sharpness developer in order to achieve a moderate gain in acutance. The gain in sharpness may be worth while, however, if the system is not grain-limited by the film emulsion. The fine-grain developer achieves its improvement in image structure but results in a loss of emulsion speed. This loss, in some measure, tends to offset the gain in acutance, with increased granularity, of the high-definition developer that requires no exposure increase. Thus, there is no clear-cut advantage for either the fine-grain or the high-sharpness developer, but the choice must be determined by the individual requirements of the film user.

### Formulas for High-Definition Developers

High-definition developers are usually used with thin-layer, fine-grain photographic films of low or moderate speed. These films tend to produce

Table 2. Effect of Developer on Structure of Images: Speed, Acutance, and Granularity of Kodak Panatomic-X Film<sup>a</sup>

| Series                                  | Formula No.       | Kodak Elon | Sulfite (g/liter) | Dev. Time (min) | Contrast |  | Speed |     | Acutance |     | Granularity |     |
|---|-------------------|------------|-------------------|-----------------|----------|--|-------|-----|----------|-----|-------------|-----|
|   |                   |            |                   |                 | $\gamma$ |  |       | %   |          | %   |             | %   |
| I (Fine grain)                          | AH-1 <sup>b</sup> | 7.50       | 10                | 9               | 0.62     |  | 130   | 113 | 2340     | 106 | 0.027       | 123 |
|   | AH-2              | 7.50       | 30                | 8               | 0.63     |  | 125   | 108 | 2200     | 100 | 0.019       | 86  |
|   | AH-3              | 7.50       | 100               | 8½              | 0.63     |  | 82    | 71  | 2200     | 100 | 0.011       | 50  |
|   | AH-4              | 7.50       | 200               | 11              | 0.63     |  | 96    | 83  | 1850     | 84  | 0.012       | 55  |
| II (High sharpness)                     | AH-1 <sup>d</sup> | 7.50       | 10                | 9               | 0.62     |  | 130   | 113 | 2340     | 106 | 0.027       | 123 |
|   | AH-15             | 2.50       | 10                | 4               | 0.61     |  | 107   | 93  | 2500     | 113 | 0.034       | 155 |
|   | AH-16             | 1.00       | 10                | 5               | 0.61     |  | 117   | 102 | 2550     | 116 | 0.036       | 164 |
|   | AH-17             | 0.50       | 10                | 7               | 0.69     |  | 129   | 112 | 2750     | 125 | 0.036       | 164 |
| Kodak Developer D-76 (1:1) <sup>c</sup> | AH-18             | 0.25       | 10                | 13              | 0.64     |  | 150   | 130 | 3100     | 141 | 0.034       | 155 |
|   |                   |            |                   | 6½              | 0.62     |  | 115   | 100 | 2200     | 100 | 0.022       | 100 |

<sup>a</sup> All data from single runs except as noted.

<sup>b</sup> Average of five runs.

<sup>c</sup> Average of two runs.

<sup>d</sup> Data repeated for convenience.

Table 3. Effect of Developer on Structure of Images: Speed, Acutance, and Granularity of Kodak Tri-X Film<sup>a</sup>

| Series                            | Formula No.       | Kodak Elon | Sulfite (g/liter) | Dev. Time (min) | Contrast |  | Speed |     | Acutance |     | Granularity |     |
|-----------------------------------|-------------------|------------|-------------------|-----------------|----------|--|-------|-----|----------|-----|-------------|-----|
|                                   |                   |            |                   |                 | $\gamma$ |  |       | %   | %        |     | %           | %   |
| I (Fine grain)                    | AH-1 <sup>b</sup> | 7.50       | 10                | 22              | 0.62     |  | 1090  | 128 | 950      | 79  | 0.074       | 132 |
|                                   | AH-2              | 7.50       | 30                | 20              | 0.67     |  | 910   | 107 | 1150     | 96  | 0.064       | 114 |
|                                   | AH-3              | 7.50       | 100               | 16              | 0.65     |  | 590   | 70  | 700      | 58  | 0.050       | 89  |
|                                   | AH-4              | 7.50       | 200               | 20              | 0.64     |  | 525   | 62  | 500      | 42  | 0.050       | 89  |
| II (High sharpness)               | AH-1 <sup>d</sup> | 7.50       | 10                | 22              | 0.62     |  | 1090  | 128 | 950      | 79  | 0.074       | 132 |
|                                   | AH-15             | 2.50       | 10                | 11              | 0.62     |  | 852   | 100 | 900      | 75  | 0.082       | 147 |
|                                   | AH-16             | 1.00       | 10                | 11½             | 0.62     |  | 795   | 94  | 900      | 75  | 0.084       | 150 |
|                                   | AH-17             | 0.50       | 10                | 26              | 0.67     |  | 795   | 94  | 1050     | 88  | 0.086       | 154 |
|                                   | AH-18             | 0.25       | 10                | 35              | 0.62     |  | 742   | 87  | 1150     | 96  | 0.090       | 161 |
| Kodak Developer D-76 <sup>c</sup> |                   |            |                   | 8½              | 0.63     |  | 850   | 100 | 1200     | 100 | 0.056       | 100 |

<sup>a</sup> All data from single runs except as noted.<sup>b</sup> Average of five runs.<sup>c</sup> Average of two runs.<sup>d</sup> Data repeated for convenience.

### High-Acutance Developers

contrast easily, often excessively. A soft-working developing agent, usually Metol or Phenidone, will yield acceptable contrast and a good tonal scale in a suitable developing composition. A Metol-only developer produces a greater increase in the density of fine image detail than does a Metol-hydroquinone developer. The concentration of the developing agent or agents is very low, insuring that the developing agent will be exhausted rapidly in the heavily exposed areas of the film. The activity of the developing action is maintained by adequate alkali content to prevent losses in emulsion speed. However, it may be presumed that in areas of highly active development, the pH of the local developer may drop to a lower value. This local loss in pH would have a compensating action in itself, meaning the highly exposed areas would tend to develop at a slightly slower rate than if the solution had been highly buffered.

All conditions of development of the high-definition developer favor the formation of image edge effects. The exhaustion of the developing agent or the loss of activity caused by the formation of acid products during development restrain development in the areas of high exposure. Active developer diffusing from areas of low to high exposure will cause increased development of the boundary of the image, producing increased contour density but also increasing the size of the silver grains in the enhanced edge density. Because the high-definition developer must be carefully balanced chemically and used in dilute form, the solution is used only once, then discarded. This working solution is often prepared from a concentrated form of the developer or by mixing two solutions just before use. In some cases, conventional fine-grain developers, such as Kodak Developer D-76, are diluted with water to form the dilute developing solution that gives increased image edge effects, resulting in increased acutance values for the image.

### HIGH-ACUTANCE DEVELOPERS

Typical high-definition one-use developers are those of Beutler (below) and Crawley (Table 4).

| Beutler Formula <sup>49</sup> |         |         |             |             |         |
|-------------------------------|---------|---------|-------------|-------------|---------|
| Solution A:                   | Water   | 1000 ml | Solution B: | Water       | 1000 ml |
|                               | Metol   | 10 g    |             | Sodium      | 50 g    |
|                               | Sodium  | 50 g    |             | carbonate   |         |
|                               | sulfite |         |             | (anhydrous) |         |

Add 50 ml solution A and 50 ml solution B in turn to 500 ml water. Development: 7 to 10 min, 65°F.



Table 4. Crawley FX Acutance Developers<sup>54</sup>

| FX-1 High-Acutance Developer<br>(working solution) | FX-2 Acutance Developer<br>(working solution) | FX-13 Acutance Developer<br>(working solution) |
|--|---|--|
| Metol  | Metol   | Metol  |
| Sodium sulfite<br>(anhydrous)                      | Sodium sulfite<br>(anhydrous)                 | Sodium sulfite<br>(anhydrous)                  |
| Sodium carbonate<br>(anhydrous)                    | Glycin  | Glycin   |
| Potassium iodide<br>(0.001% solution)              | Potassium carbonate                           | Potassium iodide<br>(0.001% solution)          |
| Water to make                                      | Pinakryptol yellow<br>(1:2000 solution)       | Water to make                                  |
| 1000 ml  | Water to make                                 | 1000 ml  |
| (Speed increase: $\frac{1}{2}$ to 1 stop)          | (Speed increase: 80%)                         | (Speed increase: $\frac{1}{2}$ stop)           |

Developing time: approximately 12 to 18 min, 68°F, for FX-1 and FX-2. For FX-13, use times about two-thirds those given for FX-1 and FX-2. Use FX-13 only with slow-speed films. Faster film materials may show grain and definition disadvantages.

A modification of the Beutler formula has been suggested by Arthur Kramer.<sup>52</sup> Potassium iodide was added to increase the surface action and promote edge effects. Add one part of solution A, one part of solution B, and eight parts of water. For each liter of this solution add 2.5 ml of a 0.001% solution of potassium iodide. Kodak Plus-X film was processed for 10 min at 68°F.

Another modification has been suggested for the popular Beutler formula.<sup>53</sup> To 150 ml of Beutler solution A (use only the A solution), 21.2 g of sodium sulfite and 8.5 g of sodium chloride were added. The solution was made to a volume of 300 ml by adding water. A 9-min, 68°F development was proposed for Ilford FP3 film.

## COMPENSATING DEVELOPERS

For subjects with great lighting contrasts, special techniques are used: modulation of exposure is combined with a special developing solution to provide optimum reproduction of subjects that are incapable of adequate rendition with normal developers. (See Figure 7.) Exposure is often based on the shadow readings to insure satisfactory detail rendering, then the negative is developed in a dilute developing solution of low buffering capacity. In the areas of highest exposure the developing agent is quickly exhausted, but the shadow portions of the negative continue to develop. Edge effects also are produced. The developing solution produces less density than normally would result in the high-exposure areas, that is, the developer compensates for the high exposures to produce a usable negative. Such compensation is quite striking: the classic demonstration involves photographing a lighted clear glass light bulb against the page of a book. A compensating developer produces a negative that shows the sharply defined filament with the letters of the printed matter clearly readable.

Hans Windisch<sup>55</sup> proposed such a compensating developer for extreme lighting contrasts:

### Windisch Catechol Compensating Developer

|                    |                              |        |                    |           |        |
|--------------------|------------------------------|--------|--------------------|-----------|--------|
| <i>Solution A:</i> | Water (boiled)               | 100 ml | <i>Solution B:</i> | Water     | 100 ml |
|                    | Catechol                     | 8 g    |                    | Sodium    | 10 g   |
|                    | Sodium sulfite<br>(crystals) | 2.5 g  |                    | hydroxide |        |

Tank development: 500 ml water + 12 ml solution A + 7 ml solution B. Development for 15 to 20 min, 68°F. Agitate "thoroughly" during development.



Figure 7. A compensating film developer produces negatives that yield prints with increased shadow detail. The negative for photograph (a) was given recommended development in a commercial Metol-sodium sulfite developer; the negative for photograph (b) was developed in a compensating pyrogallol developer. In the original prints, more shadow detail and better line rendition (the cables at the top of the crane, for example) are evident in the print from the negative developed in the compensating developer. (James King, Eastman Kodak Company)

A technique involving exposure control and development compensation was proposed by Willi Beutler to bridge great lighting contrasts.<sup>56</sup> Exposure readings are taken of highlight and shadow to establish the luminance range. The shadow readings are then increased by a factor that is related to the luminance range.

| Luminance Ranges | Exposure Factors | Development Times* |
|------------------|------------------|--------------------|
| 1:25 to 1:100    | 2×               | 12 min, 65°F       |
| 1:100 to 1:300   | 3×               | 10 min, 65°F       |
| 1:300 to 1:500   | 4×               | 8 min, 65°F        |

\* Applies to medium-speed panchromatic film. Add 2 min for high-speed film.



Figure 7. (continued)

The developer is made as a stock solution:

|                           |         |
|---------------------------|---------|
| Metol                     | 10 g    |
| Sodium sulfite, anhydrous | 50 g    |
| Water to make             | 1 liter |

One part of the above solution is mixed with four parts of water to make the working solution. An acetic acid stop bath is suggested for strongly over-exposed negatives to stop development quickly.

The superadditivity of Phenidone-pyrogallol developers was studied by Marilyn Levy.<sup>57</sup> A new compensating developer based on these findings was proposed by Silom Horwitz<sup>58</sup> and is shown on the following page:

## Negative Developer D-512 (Horwitz)

|                           |         |
|---------------------------|---------|
| Calgon                    | 1 g     |
| Sodium sulfite, anhydrous | 40 g    |
| Pyrogallol                | 6 g     |
| Phenidone                 | 2 g     |
| Water to make             | 1 liter |

Dilute one part of this solution with one part of water to make working solution. Development time is 10 min, 68°F (20°C), for Kodak Plus-X film or Agfa IF or ISS film, with exposure at the rated speed. The use of Developer D-512 should be restricted to high-contrast scenes and not be used for normal-contrast subjects.

## DIVIDED DEVELOPMENT

Development in two solutions is an old processing technique. A multitude of variations exist. In some cases development is carried out in two separate solutions of the same developing composition. A given volume of D-76 developer has been found to provide more uniform development and less loss in emulsion speed during exhaustion when divided into two baths than when used as a single bath.<sup>59</sup> In other cases development may be started in a weak developing solution and finished in another of different activity.<sup>60</sup> But the most common form of divided development consists of a first solution that contains the developing agents and sodium sulfite without alkali present. No image is developed in this solution. When the photographic material is transferred to an alkaline solution that is the second bath, the image is formed by the imbibed developing agents retained in the emulsion layer. In 1885 E. Audra<sup>61-63</sup> proposed such a two-bath developer and was one of the first to make use of the ability of gelatin layers to absorb a considerable quantity of processing solution. Audra's formula for the first developing solution was as follows:

|                 |              |
|-----------------|--------------|
| Sodium sulfite  | 25 parts     |
| Distilled water | 100 parts    |
| Sulfuric acid   | 1 drop/30 ml |
| Pyrogallol      | 10 parts     |

For use, one part of this solution was combined with ten parts of water. The photographic plate was immersed for more than a minute, drained for 3 or 4 sec, then immersed in

|                                      |           |
|--------------------------------------|-----------|
| Sodium sulfite, 25% solution         | 10 parts  |
| Sodium carbonate, saturated solution | 3 parts   |
| Water                                | 100 parts |

The developing agent—pyrogallol—was imbibed in the gelatin layer of the photographic plate in the first solution, then activated in the alkaline second solution. This processing technique evoked considerable interest and was quickly modified to suit the needs of others.<sup>64-66</sup>

The two-bath development procedure provides a fixed degree of development. A limited volume of solution containing the developing agent is absorbed in the emulsion layer in the first bath; only this given quantity is available to develop the image in the second solution. Two-bath development can produce results similar to compensating development, less image being formed in the highly exposed areas because of exhaustion of the developing agent. Such a condition may produce image-enhancing edge effects and possibly increased granularity. Development times and temperature are not critical, but the two solutions should be kept near the same temperature. A moderate degree of agitation may be necessary to both solutions to insure image uniformity. Overdevelopment is impossible when dilute solutions are used. Two-bath development has been suggested for overexposed film or for exposures of contrasty subjects.<sup>67</sup>

Scientific studies of two-bath development are scarce, but this technique was considered for motion picture film processing by J. I. Crabtree, H. Parker, Jr., and H. D. Russell.<sup>59</sup> They concluded that "In no case is it possible to obtain absolutely uniform development properties throughout the life of a developer, but by the use of two-bath developers this condition is approached much more nearly than with single-bath developers which are suitably revived. The two-bath developers give a practically constant gamma or degree of image contrast throughout their life, and the emulsion speed loss is less than with single-bath developers." In a single-bath developer, bromide ions accumulate, delaying the start of development. During this induction period it has been suggested<sup>68-69</sup> that the solvent effect of the sodium sulfite present causes a loss in latent image, reducing the film speed. In a two-bath developer, development should not occur in the first bath, so that no bromide ions are released. The time of immersion in the first solution should not be extended if sodium sulfite is present. Crabtree, Parker, and Russell added sugar to delay image appearance as well as sodium bisulfite to lower the



alkalinity of the first bath. They proposed a two-bath developer that required a 4-min immersion in each of these solutions for panchromatic films:

## Formula SD-4

## Solution A—First Bath

|                            |           |
|----------------------------|-----------|
| Metol                      | 5.0 g     |
| Hydroquinone               | 2.0 g     |
| Sodium sulfite, desiccated | 100.0 g   |
| Sugar                      | 100.0 g   |
| Sodium bisulfite           | 5.0 g     |
| Water to make              | 1.0 liter |

## Solution B—Second Bath

|                              |           |
|------------------------------|-----------|
| Sodium carbonate, desiccated | 10.0 g    |
| Sodium sulfite, desiccated   | 100.0 g   |
| Potassium bromide            | 0.5 g     |
| Potassium iodide             | 0.01 g    |
| Water to make                | 1.0 liter |

A more rapid-acting version of SD-4 was formulated by H. Parker and J. I. Crabtree.<sup>70</sup> Rapid Two-Bath Developer SD-6 was "satisfactory since it prevents excessive swelling, provides rapid and thorough hardening of the gelatin while in the developer, and allows the use of comparatively high processing temperatures. Also, it automatically eliminates the danger of overdevelopment and provides an almost constant degree of development in spite of variations in the time of treatment which can otherwise easily occur in hand processing for such short times." The time of treatment was 1 min in each bath without intermediate rinsing at a preferred temperature of 75 to 80°F. A water rinse or acid stop bath followed by fixation and a brief wash completed the processing. The formula for SD-6 two-bath developer contained:

## Solution A

|                              |         |
|------------------------------|---------|
| Water (about 125°F [52°C])   | 500 ml  |
| Metol                        | 3 g     |
| Sodium sulfite, desiccated   | 25 g    |
| Hydroquinone                 | 6 g     |
| Sodium sulfate, desiccated   | 100 g   |
| Sodium carbonate, desiccated | 20 g    |
| Water to make                | 1 liter |

## Solution B (two parts)

## Part 1

|                                  |         |
|----------------------------------|---------|
| Water (about 125°F [52°C])       | 500 ml  |
| Phenosafranine (1:1000 solution) | 20 ml   |
| Sodium sulfite, desiccated       | 50 g    |
| Potassium bromide                | 2 g     |
| Water to make                    | 1 liter |

## Part 2

|                         |         |
|-------------------------|---------|
| Formalin (40% solution) | 200 ml  |
| Water to make           | 1 liter |

To make solution B add equal volumes of part 1 and part 2 before using.

The popularity of the 35mm camera during the late 1930s and the 1940s caused continued interest in the two-bath processing of 35mm negatives to produce fine-grain and high-definition images. One of the early two-bath developers was proposed by E. Leitz and became subject to many variations. This developer consisted of:

|                             | 1938 Version <sup>71</sup> | Modern Version <sup>72</sup> |
|-----------------------------|----------------------------|------------------------------|
| <i>Solution A</i>           |                            |                              |
| Water                       | 1 liter                    | 1 liter                      |
| Metol                       | 3 g                        | 5 g                          |
| Sodium sulfite, anhydrous   | 30 g                       | 100 g                        |
| <i>Solution B</i>           |                            |                              |
| Water                       | 1 liter                    | 1 liter                      |
| Sodium carbonate, anhydrous | 14.8 g                     | 15 g                         |
| Sodium sulfite, anhydrous   | 3.24 g                     | 6 g                          |

Medium-speed film was immersed for 6 to 8 min in solution A, and 3 to 4 min in solution B, without a rinse between solutions. Solution temperature was 65°F for both solutions. Treat thin-emulsion film for 4 min in the first solution; for fast films the time of immersion is 8 to 10 min. Best results were said to be obtained when the normal speed of the film was multiplied by two.

The Leitz two-bath formula and several others were included in a summary of two-bath development by the magazine, *Miniature Camera World*. Table 5, a chart of two-bath formulas and processing directions, is derived from that magazine.<sup>73</sup>

Table 5. Summary of Two-Bath Development<sup>a</sup>

| Ingredients                      | Leitz Two-Bath | Symon <sup>74</sup><br>(Modified DK-20) | Stoekler<br>High-Speed | Stoekler<br>Fine Grain | Agfa<br>High-Speed | Jacobson<br>(Formula 124) <sup>75</sup> | Meritol Caustic <sup>76-80</sup> | MCW 3 <sup>81,82</sup> |
|----------------------------------|----------------|---|------------------------|------------------------|--------------------|---|----------------------------------|------------------------|
| <b>Solution A</b>                |                |   |                        |                        |                    |   |                                  |                        |
| Metol                            | 5              | 5                                       | 2                      | 5                      | 5                  | 5                                       |                                  | 2                      |
| Sodium sulfite<br>(anhydrous)    | 100            | 100                                     | 100                    | 100                    | 30                 | 100                                     | 90                               | 60                     |
| Hydroquinone                     |                |   | 5                      |                        | 10                 | 2                                       |                                  | 7                      |
| Meritol                          |                |   |                        |                        |                    |   | 16                               |                        |
| Pot. thiocyanate                 |                | 1.0                                     |                        |                        |                    |   |                                  |                        |
| Pot. bromide                     |                | 0.5                                     |                        |                        |                    |   |                                  |                        |
| Cane sugar                       |                |   |                        |                        |                    | 100                                     |                                  |                        |
| Sodium bisulfite                 |                |   |                        |                        |                    | 5                                       |                                  |                        |
| Kodalk                           |                |   |                        |                        |                    |   |                                  | 6                      |
| Borax                            |                |   | 2                      |                        |                    |   |                                  |                        |
| Water to<br>(in liters)          | 1              | 1                                       | 1                      | 1                      | 1                  | 1                                       | 1                                | 1                      |
| <b>Solution B</b>                |                |   |                        |                        |                    |   |                                  |                        |
| Caustic soda<br>(sod. hydroxide) |                |   | 10 <sup>b</sup>        |                        |                    |   | 100 <sup>b</sup>                 | 70 <sup>b</sup>        |
| Pot. bromide                     |                |   | 10 <sup>b</sup>        |                        |                    |   |                                  |                        |
| Sod. carbonate<br>(anhydrous)    | 15             |   |                        |                        | 125                | 10                                      |                                  | (100 <sup>b</sup> )    |
| Kodalk                           |                | 20                                      |                        |                        |                    |   |                                  |                        |
| Borax                            |                |   |                        | 10                     |                    |   |                                  |                        |
| Sod. sulfite<br>(anhydrous)      | 6              |   |                        |                        |                    | 100                                     |                                  |                        |
| Water to<br>(in liters)          | 1              | 1                                       | 1                      | 1                      | 1                  | 1                                       | 1                                | 1                      |

<sup>a</sup> All weights in grams.<sup>b</sup> Can be compounded from 10% stock solution.Using the Two-Bath Table<sup>73</sup>

General: No preliminary wetting or forebath should be given, except in the case of Meritol-caustic which sometimes needs a one-minute soak with agitation in a one per cent (anhydrous) sodium sulphite solution to remove the film's coloured backing. The A bath should be poured into the loaded tank quickly and the film agitated for the times indicated (the shorter time being for the slower film) then poured out and re-stored. No rinse should be given, but B should be poured in and the film agitated for the times shown after which the B bath should be quickly poured out and an acid-stop used prior to the usual method of fixing. The B bath may in some cases be stored for further use, but it is so cheap that this seems scarcely worth while if consistent results are aimed at.

Leitz (Leica) two-bath: 3-6 min in A: 3 min in B, at a temperature of 65°F.

Symon: 6-15 minutes in A; the working B bath is made by diluting the stock bath to one-tenth its strength (to give a 0.2% solution of Kodalk) discarding it after use. Immerse the film for 3½ min. in the B bath.

Stoekler high-speed: Medium speed films need approximately 1½ min. in A followed immediately by 30 sec. in B. Then use an acid stop bath immediately. (65°F.)

Stoekler fine-grain: As for the Leitz two-bath.

Agfa high-speed: One minute with agitation at 70°F. in A followed by one minute with agitation in B and an acid stop bath. 5°F. rise or fall in temperature corresponds with about 25% decrease or increase in these times. Increasing the time in the B bath increases the contrast.

Jacobson (formula 124 from *Developing*): Films need about 5 min in A and about 4 to 6 min in B solution.

Meritol Caustic: Three minutes in each bath. The A bath must be diluted to a specified degree for each type of film.

MCW 3: Working at 65°F. (a) using the carbonate as the B bath give three minutes in each bath. The B bath is made by diluting the 10% stock solution "one in four"; (b) using the caustic solution as the B bath give one minute in A and two minutes in the B bath. The working bath is of 0.7% strength (this does not appear to be critical) and is made by diluting the stock bath "one in ten," throwing this away after use.

## Two-Bath Development with Borax

The fine-grain development given by Kodak developer D-76 containing borax has spurred interest in the use of borax as the alkali in the second bath of a two-bath developer. Indeed, D-76 itself has been divided into two baths by Robert J. Starks. According to Paul Farber,<sup>83</sup> "The maximum emulsion speed afforded by D-76 is retained, along with the high acutance. However, the divided development gives the negatives a beautiful range of tones which straight D-76 cannot seem to do over a large range of contrast situations."

The formula for divided D-76 consists of:

#### Solution A

|                            |           |
|----------------------------|-----------|
| Metol                      | 2.0 g     |
| Sodium sulfite, desiccated | 100.0 g   |
| Hydroquinone               | 5.0 g     |
| Potassium bromide          | 1.0 g     |
| Water to make              | 1.0 liter |

#### Solution B

|               |           |
|---------------|-----------|
| Borax         | 50.0 g    |
| Water to make | 1.0 liter |

Immerse film in solution A for 3 min, then in solution B for 3 min. Agitate the film for the first 5 sec of each minute. Another variation consists of developing the film for one-half the normal time in regular D-76, then transferring it for 2 min to a solution containing 5 g of borax and 30 g of sodium sulfite (anhydrous) in a liter of water.<sup>84</sup>

Metol is often stated to be the only developing agent which yields fine-grain images of good tonal gradation, as recently reiterated by L. B. Dalzell,<sup>85-86</sup> who proposed to improve the classic 1938 two-bath formula of Henrich Stoeckler by reducing the content of sodium sulfite to yield improved acutance. These solutions had the composition:

#### Solution 1

|                           | Stoeckler (1938) | Dalzell (1967) |
|---------------------------|------------------|----------------|
| Water (40 to 50°C)        | 750 ml           | 750 ml         |
| Metol                     | 5 g              | 5 g            |
| Sodium sulfite, anhydrous | 100 g            | 75 g           |
| Water to make             | 1 liter          | 1 liter        |

#### Solution 2

|               |         |         |
|---------------|---------|---------|
| Borax         | 10 g    | 10 g    |
| Water to make | 1 liter | 1 liter |

Immerse film for 3 or 4 min in each of the two solutions, agitating every 30 sec in each. Uniform results were reported with 35mm Agfa ISS, Kodak Panatomic-X film (at index of ASA 100), Plus-X (ASA 160), and Tri-X film (ASA 400). The Stoeckler-made formula cited earlier in this section (1938 Leitz two-bath) contained only 30 g of sodium sulfite in the first solution.

Two-bath development, writes Helmut Gerlatzek,<sup>87</sup> "achieves a quality of detail in the shadows such as is unattainable in any other way while at the same time precluding all possibility of excessive density in the highlights." Gerlatzek, however, disagrees that Metol is the only developing agent that can provide fine-grain images with soft gradation. He proposed a Phenidone-hydroquinone first solution with low sulfite content:

#### Solution A

|                           |         |
|---------------------------|---------|
| Water                     | 1 liter |
| Sodium sulfite, anhydrous | 50 g    |
| Hydroquinone              | 5 g     |
| Phenidone                 | 0.3 g   |
| Potassium bromide         | 0.5 g   |

#### Solution B

|                   |         |
|-------------------|---------|
| Water             | 1 liter |
| Borax, crystal    | 20 g    |
| Boric acid        | 10 g    |
| Potassium bromide | 0.5 g   |

The film is first treated in solution A for 4 min with the usual agitation, the solution temperature being between 16 and 24°C. The film is drained briefly and then transferred without rinsing to solution B at 20°C for 4 min. The film is then briefly immersed in 2% acetic acid, rinsed in water, and fixed in the usual manner.

A Metol-hydroquinone first solution was proposed as early as 1938 by C. H. Shipman<sup>88-90</sup> with the option of a second bath of sodium carbonate or borax. The borax second solution was for the finer-grained images needed by small negatives. The formulations are given at the top of the next page. For use, temperature of solutions may vary from 70 to 80°F. Photographic material is immersed in solution A for 1 min, then drained but not rinsed before being placed for 1 min in solution B or 3 min in solution C. A similar divided developer has been recommended for tropical use.<sup>91</sup>



## Solution A

|                           |        |
|---------------------------|--------|
| Water (120°F for mixing)  | 946 ml |
| Metol                     | 6.2 g  |
| Sodium sulfite, anhydrous | 32.4 g |
| Hydroquinone              | 6.2 g  |
| Potassium bromide         | 2.6 g  |
| Sodium chloride           | 0.2 g  |

## Solution B

|                             |        |
|-----------------------------|--------|
| Water (120°F for mixing)    | 946 ml |
| Sodium carbonate, anhydrous | 97.2 g |

## Solution C

|                          |        |
|--------------------------|--------|
| Water (120°F for mixing) | 946 ml |
| Borax                    | 51.8 g |

Paul Farber,<sup>92</sup> who has been active in promoting modern two-bath development, has proposed a Metol-hydroquinone solution of great versatility. The baths for Farber's divided developer consist of:

## Solution A

|                              |         |
|------------------------------|---------|
| Distilled water (80°F)       | 750 ml  |
| Metol                        | 6 g     |
| Sodium sulfite, anhydrous    | 50 g    |
| Hydroquinone                 | 3 g     |
| Potassium bromide            | 3 g     |
| Sodium chloride (table salt) | 0.5 g   |
| Distilled water to make      | 1 liter |

## Solution B

|                                |         |
|--------------------------------|---------|
| Distilled water (80°F)         | 750 ml  |
| Sodium sulfite, anhydrous      | 10 g    |
| Sodium carbonate, monohydrated | 50 g    |
| Distilled water to make        | 1 liter |

## Solution C (Fine Grain)

|                           |         |
|---------------------------|---------|
| Distilled water (80°F)    | 750 ml  |
| Sodium sulfite, anhydrous | 10 g    |
| Borax (photo grade)       | 50 g    |
| Distilled water to make   | 1 liter |

Film is to be treated 2 min in solution A, then without rinse or stop bath, 2 min in solution B. Agitation is 5 sec every 30 sec in both baths. When using solution C, increase the immersion time to 4 min in this bath. Chemical modifications were proposed to change the performance of the divided developer. Increasing the sodium sulfite from 50 to 100 g in solution A will produce finer grain but will lower the edge sharpness between adjacent image details. Image contrast may be changed by varying the content of hydroquinone in solution A. Higher contrast can be obtained by increasing the hydroquinone concentration from 3 to 6 g (even higher with 10 g). Lower contrast resulted when the hydroquinone was present at a 1-g quantity or eliminated entirely. These modifications can also be employed when using solutions A and B as a two-solution paper developer. A 45-sec treatment in both baths, with an intermediate drain, was recommended with agitation in both baths.

Sodium metaborate can be formed by mixing borax and sodium hydroxide to produce a substance of higher alkalinity than borax. This invention of Harold D. Russell<sup>93</sup> has been sold in a hydrated form as Kodalk balanced alkali ( $\text{Na}_2\text{B}_2\text{O}_4 \cdot 8\text{H}_2\text{O}$ ). Sodium metaborate, or Kodalk, has been used for preparing the second solution of a two-bath developer. For controlling the contrast of negatives exposed with harsh lighting, Ansel Adams<sup>94</sup> has proposed this two-solution developer:

## Solution I

|                            |         |
|----------------------------|---------|
| Metol                      | 7.5 g   |
| Sodium sulfite, desiccated | 100 g   |
| Water to make              | 1 liter |

## Solution II

|                            |         |
|----------------------------|---------|
| Sodium metaborate (Kodalk) | 10 g    |
| Water to make              | 1 liter |